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Comparing effectiveness of additive, interactive and quadratic models in detecting combined effects of achievement goals on academic attainment

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ABSTRACT

This study compared effectiveness of additive, interactive, and quadratic statistical models in detecting the combined effects of achievement goals on academic achievement. In a prospective study that aimed to predict college students' grades in an English course, we found that the quadratic model was more effective in detecting the combined effects of achievement goals on course grades than the additive and interactive models. In addition, a response surface analysis showed that the combined effects of achievement goals on course grades corresponded to a goal profile that involved tendencies to endorse mastery goals at high levels and performance goals at moderate levels. Findings suggest that the quadratic model is a viable data analytic technique that assists researchers in detecting combined effects of achievement goals on academic achievement.

1. Introduction

The study of achievement motivation has long been concerned with the question of which types of goals are most strongly associated with desirable outcomes such as high levels of self-esteem, intrinsic motivation, productivity in the workplace, and academic performance. Building upon Nicholls' (1989) or Dweck's (1986) achievement goal theories, early research distinguished between two major classes of achievement goals: mastery goals that focus on developing competence through task mastery and learning, and performance goals that focus on demonstrating competence by outperforming others (Duda, 1989). This dichotomous conceptualisation of achievement goals has since been extended to a 2 × 2 hierarchical model that differentiated achievement goals into mastery-approach goals (i.e., understand and master a task), mastery-avoidance goals (i.e., avoid misunderstanding or making mistakes), performance-approach goals (i.e., try to do better than others) and performance-avoidance goals (i.e., avoid doing poorly relative to others) (Elliot, 1999; Elliot & Church, 1997; Elliot & McGregor, 2001).

To date, research has generally shown that avoidance goals (mastery-avoidance or performance-avoidance goals) are almost uniformly associated with maladaptive outcomes such as high anxiety, disorganised study habits, fear or failure, self-handicapping, and low achievement or task interest (Senko, Huleman, & Harackiewitz, 2011). Mastery-approach and performance-approach goals have been associated with adaptive outcomes such as elevated task (mental) focus (Lee, Sheldon, & Turban, 2003), task absorption (Barron & Harackiewicz, 2001) or positive peer relationships and classroom belongingness (Senko et al., 2011). However, in comparison to performance-approach goals, mastery-approach goals are more strongly associated with high intrinsic motivation, high task-interest, and use of deep learning strategies (Harackiewicz, Barron, Carter, Lehto, & Elliot, 1997; Harackiewicz, Barron, Tauer, Carter, & Elliot, 2000; Harackiewicz, Durik, Barron, Linnenbrink, & Tauer, 2008). Interestingly, performance-approach goals exhibit a stronger relationship with academic achievement than mastery-approach goals (Senko et al., 2011; Van Yperen, Blaga, & Potmes, 2014). Nevertheless, a number of studies clarified that the positive effects of performance-approach goals on educational outcomes are specific, and they are more likely to be observed among boys than girls, among older students than younger students, in competitive learning environments and if mastery goals are also endorsed at high levels (Midgley, Kaplan, & Middleton, 2001; Richardson & Remedios, 2014).

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The adaptive effects of performance-approach and mastery-approach goals on the same or distinct outcomes have compelled researchers to examine the extent to which the two types of approach goals combine to optimise performance, and the processes involved (Harackiewicz, Barron, & Elliot, 1998). According to this multiple goal perspective, students who adopt both mastery-approach and performance-approach goals may experience more positive outcomes than students who adopt only one type of goal. The reason for this is that students who endorse both types of approach goals may reap the benefits associated with each goal by pursuing both goals simultaneously (Senko et al., 2011). Accordingly, Barron and Harackiewicz (2001) advised researchers to examine combined effects of achievement goals on outcomes by testing additive and interactive statistical models. However, to our knowledge, only six studies have supported combined effects of performance-approach goals and mastery-approach goals on academic achievement using additive or interactive models (see Table 1).

One reason why previous research has been inconsistent in observing combined effects of achievement goals on academic achievement is that quadratic terms, which test for non-linear functional relationships, are not included in the additive and interactive models (Aiken & West, 1991, p. 62; Cortina, 1993; Krantz & Tversky, 1971; Lubinski & Humphreys, 1990). This practice can mislead researchers to reject a combined effect when, in fact, there is an alternative model that supports combined effects of achievement goals on academic achievement (Ganzach, 1997). Given this, the purpose of the present article was to compare utility of the additive, interactive, and quadratic regression models in detecting combined effects of achievement goals on academic performance.

2. Differences between additive, interactive, and quadratic models

According to the multiple goal approach, the additive or interactive models can be tested by examining whether the following regression equation explains observations (Barron & Harackiewicz, 2001):

$$TP = b_0 + b_1M + b_2P + b_4M \times P + e_1 \quad (1)$$

In Eq. (1), TP represents students' performance on educational tasks as reflected, for example, on grades achieved in an exam. The terms M and P are individuals' responses to instruments measuring mastery goals and performance goals. The product term $M \times P$ represents the interaction between performance goals and mastery goals. The coefficient b_0 is the intercept of the regression equation. The term e_1 indicates residual variance that is not explained by the regression equation. The coefficients b_1, b_2 and b_4 are unstandardised regression coefficients indicating the main and interactive effects of mastery goals or performance goals on task performance.

Eq. (1) supports the additive model if the main effects of mastery goals and performance goals on task performance are positive and statistically significant (Senko et al., 2011). In this case, the additive model supports the notion that task performance is maximised, in the sense that it reaches the highest possible level, when mastery goals and performance goals are also endorsed at the highest possible levels (Barron & Harackiewicz, 2001). A statistically significant value for b_4 indicates presence of an interaction effect whereas a statistically nonsignificant b_4 does not support an interaction (Aiken & West, 1991). A positive b_4 implies a type of interactive effect, termed synergistic, when the main effects of achievement goals on course grades are zero or positive. In these cases, the interactive effect indicates that, among students who endorse mastery goals at high levels, those students who also endorse performance goals at high levels achieve higher performance levels than all other students.

The quadratic model is estimated by introducing quadratic terms into Eq. (2) (Edwards, 1994):

$$TP = b_0 + b_1M + b_2P + b_3M^2 + b_4M \times P + b_5P^2 + e_1 \quad (2)$$

In this equation, M^2 and P^2 are quadratic terms that represent nonlinear relationships between achievement goals and task performance. The coefficients b_3 and b_5 are unstandardised regression coefficients that capture effects associated with the quadratic terms. In Eq. (2), negative values of b_3 or b_4 imply a concave-shaped relationship between achievement goals and task performance. A relationship is concave in shape when performance levels increase as achievement goals increase but only up to a given point beyond which any further increases in achievement goals will yield lower (or the same) performance levels. Hence, a concave function indicates that achievement goals yield higher performance levels when they are endorsed at a moderate level (Edwards & Parry, 1993). In contrast, positive values of b_3 or b_4 imply a convex function and that performance levels decrease (or remain constant) as achievement goals increase but up to a point beyond which further increases in achievement goals increase task performance. Accordingly, a convex function yields low performance levels when achievement goals are endorsed at moderate levels (Edwards & Parry, 1993).

An important difference between the additive, interactive, and quadratic models concerns the types of combined effects that these models enable researchers to test during the analysis. The additive and interactive models enable researchers to test the hypothesis that people who endorse both mastery goals and performance goals at the highest possible levels perform best in achievement contexts. These models cannot test the hypothesis that individuals who endorse one goal at the highest possible level and the other goal at a marginally lower level are the best performers (i.e., individuals who adopt a high-mastery/moderate-performance goal profile). The reason for this is that the additive and interactive models assume that the effects of a goal (i.e., performance goal) on course grades linearly increase within high or low levels of endorsement of the other goal, i.e. the mastery goal (Edwards, 1994, 2001). As a consequence, when these models support combined effects, they always "force" researchers to conclude that a high-mastery/high-performance goal profile is the most optimal goal profile (see Appendix). However, conclusions based on additive or interactive models can be

Table 1
Characteristics of studies that detected combined effects of achievement goals on academic achievement.

Study	Performance outcome	Effects		
		Mastery goal	Performance goal	Mastery × Performance interaction
Bodmann, Hulleman, and Harackiewicz (2008)	Final grade	0.19*	0.24*	−0.08
Church, Elliot, and Gable (2001)	Final grade	0.20*	0.14*	ns
Finney, Pieper, and Barron (2004)	Semester GPA	0.09*	0.04*	ns
Pekrun, Elliot, and Maehr (2009)	Exam grade	0.11*	0.38*	ns
Senko and Harackiewicz (2005)	Exam grade	0.16*	0.28*	ns
Senko et al. (2013)	Exam grade	0.21*	0.18*	ns

Note. Parameters with an asterisk are statistically significant at $p < 0.05$ level. An additive model is supported when main effects of mastery goals and performance goals are statistically significant. A synergistic effect is supported when the interaction between mastery goals and performance goal is statistically significant. The term ns denotes nonsignificant finding from studies that did not actually report regression coefficients.